Ground Sprayers for Sagebrush Rangelands

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ABSTRACT

The use of herbicides to control brush and weeds to release forage species or to allow the seeding of desirable forage species is a valuable range improvement technique. Herbicides usually are applied aerially on rangelands because of their extent and often rugged topography. For small acreages, in remote locations, it is often impossible to obtain aerial applicators. This article describes simple modifications of power-ground sprayers to permit their use on rangelands. The modifications to booms, boom supports, and suspension can be done in typical farm shops. Techniques for calibration and tips for operating rangeland sprayers are also given.

KEYWORDS: Rangeland sprayers, herbicide application, range improvement, sprayer calibration.

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This paper contains the results of research only. Mention of pesticides does not constitute a recommendation for use, nor does it imply that the pesticides are registered under the Federal Insecticide, Fungicide, and Rodenticide Act as amended.

GROUND SPRAYERS FOR SAGEBRUSH RANGELANDS

By J. A. Young, B. A. Roundy, A. D. Bruner, and R. A. Evans[1]

INTRODUCTION

Herbicides have been used extensively to control brush on rangelands since 1950. The use of 2,4-D for the control of big sagebrush is an important range improvement tool in Nevada. Recently, other weed control-revegetation systems using herbicides have been developed by the Science and Education Administration/Agricultural Research (SEA-AR) of the U.S. Department of Agriculture in cooperation with the Nevada Agricultural Experiment Station to control cheatgrass (downy brome) to permit establishment of wheatgrass. All of these herbicides (with the exception of paraquat to control downy brome) can be applied aerially. For most rangeland conditions, aerial application is the most economical method of treating large areas; however, in Nevada, outside of a few areas of intensive crop production, there are no aerial applicators. We have found it difficult to contract with aerial applicators to apply herbicides to small acreages in most of Nevada. Aerial applicators object to long ferrying distances for aircraft, high-elevation application sites, and unimproved runways, and accordingly, must charge high rates for spraying.

With the continued reductions in grazing on public lands, it has become increasingly important for ranchers to obtain optimum production from their privately owned rangelands. The productivity of many privately owned rangelands in Nevada can be enhanced through the use of herbicides alone or herbicide application followed by seeding. Ideally, these range improvement treatments can be accomplished without hiring additional labor and without excessive cash outlays for special equipment or custom application. To accomplish these goals, the ranchers must be able to utilize, with minimum modifications, sprayers that they already own and use for crop or livestock spraying. If ranchers have to buy a sprayer for treating sagebrush rangelands, it should be of flexible enough design to spray also both croplands and livestock.

With these factors in mind, our purpose was to design and test farm shop modifications of sprayers to treat sagebrush rangelands.

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In choosing or designing a sprayer for use on sagebrush rangelands, one should consider the various essential elements of a power sprayer, that is nozzles, boom, pump, power unit, and tank, and their compatibility and the acreage to be sprayed, the sprayer application rate, and the terrain to be sprayed (fig. 1).

We designed our sprayer for sagebrush rangelands by modifying a pull-type, trailer-mounted sprayer with a 300-gal tank. We have similarly modified a mounted-type sprayer with a 100-gal tank.

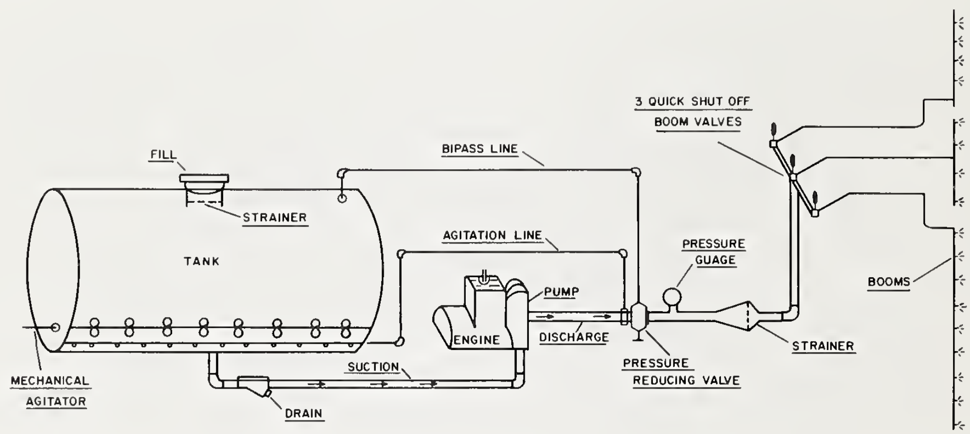

Figure 1.--Diagram of components of herbicide sprayer.

Pumps

The heart of any herbicide sprayer system is the pump. The more common types of pumps include roller, centrifugal, diaphragm, and piston. Each type of pump has advantages and disadvantages in terms of initial cost, repair cost, and efficiency. A general use pump is the centrifugal or turbine-type pump. Centrifugal pumps develop pressure from high liquid velocity imparted by the rapidly rotating impeller. As clearances are relatively high, suspended solids (from wettable powder herbicides) are not injurious to most centrifugal pumps. Single-stage centrifugal pumps must be operated at relatively high speeds. For this reason, centrifugal pumps are not as well adapted for direct drive by power takeoffs on tractors as are other type pumps. Several companies now manufacture centrifugal pump kits with belt-drive arrangements that can operate on either the new 1,000 r/m or the standard 550 r/m power takeoff. In the Midwest, this type of sprayer is very popular.

Determining Pump Size

The required pump capacity is determined by the number of nozzles, their size, and hydraulic agitation requirements. The standard formula used for calculating sprayer output is as follows:

$$FR = \frac{AR \times S \times W}{5{,}940}$$

where FR = flow rate, in gallons per minute
AR = sprayer application rate, in gallons per acre
S = speed, in miles per hour
W = width sprayed, in inches
5,940 = a constant

Using the prototype sagebrush sprayer as an example:

AR = 15 g/a
S = 1.5 m/h
W = 35 ft or 420 inches

therefore

$$FR = \frac{15 \times 1.5 \times 420}{5{,}940} = 1.59 \text{ g/m}$$

An important factor in determining required pump capacity is the type of agitation used in the spray tank. If hydraulic agitation is used through a bypass system, a greater pump capacity is required. In the hydraulic system of agitation, a pump of considerably higher capacity than that required to supply the boom is used, and the excess flow is bypassed from the spray system and forced back into the spray tank through a series of holes in a pipe passing horizontally through the bottom of the tank.

In rangeland spraying, the sprayer application rate (AR) should be kept low because of the cost of hauling water. As a tolerance factor, we set our maximum AR at 75 g/a or five times the 15 g/a used in the equation. This makes our maximum pump capacity 7.92 g/m. This does not require a very high capacity pump; therefore, the pumps of almost all farm sprayers meet the maximum requirement in terms of gallons per minute.

Power Unit

If one is buying an assembled sprayer, the manufacturer should provide a power unit of appropriate horsepower for the pump; if one is assembling a sprayer, he or she will want to determine the power requirement of the pump chosen. The pump manufacturer will usually furnish charts showing horsepower requirements at various pressure and discharge rates.

Spraying sagebrush rangeland involves operating the sprayer power unit under extremely dusty conditions. The engine should have a good quality, preferably oil bath, air cleaner. The exhaust system and muffler should be so constructed to avoid a fire hazard from accumulations of sagebrush leaves and trash. Installing a spark arrester will reduce the hazards of the exhaust starting fires. The engine for a rangeland sprayer should start easily after long periods of storage and exposure to the elements. The gas efficiency and gas storage capacity are important factors in determining the power unit for a sagebrush rangeland sprayer. Spraying at low AR's means that the sprayer engine may run out of gas before a tank load of herbicide is applied.

Booms

In spraying, the covering of a given area in a given time, when traveling at a given speed, sets the length of boom. We have determined that a 35-ft boom is a practical maximum for spraying sagebrush rangelands. Longer booms are possible if proportionally more massive modifications are completed; however, considering the topography being sprayed and the maneuverability required, the 35-ft boom appears to be an efficient unit.

Boom Support

If one is going to spray 3- to 4-ft tall sagebrush with a ground sprayer, he or she must be able to raise the boom above the level of the brush. We have determined that a boom 5 ft above the ground gives sufficient clearance over the brush and prevents the end of the boom from being driven into the ground when a tractor or trailer wheel drops into a hole or the opposite wheel raises over a rock or other obstruction.

To obtain the necessary height for boom clearance, we lengthened and strengthened the boom support mast. The boom mast supplied by the factory was removed, and structural steel angles were welded to the rear corners of the trailer frame to form the modified boom support mast (fig. 2). The mast was braced with 2- by 1-inch channel steel. A series of holes were drilled in the mast to provide for adjustable height settings for the primary boom support bracket, which was attached with a U-bolt.

We did not modify the primary boom bracket (fig. 2), but the bracket does not have to be as complex as the one shown. As we will discuss later, the boom modifications we have designed make it impossible for the booms to fold, and they must be removed for transport between jobs. The factory-supplied bracket was designed for folding booms. A simple rectangle constructed with one-inch tubing would be satisfactory.

Boom Types and Construction

The booms supplied with the sprayer were constructed of one-inch-diameter tubing. The herbicide is not carried to the nozzles in the metal tubing. The metal tube provides support for hoses that distribute the herbicide solution to the nozzles. This is called a dry-type boom.

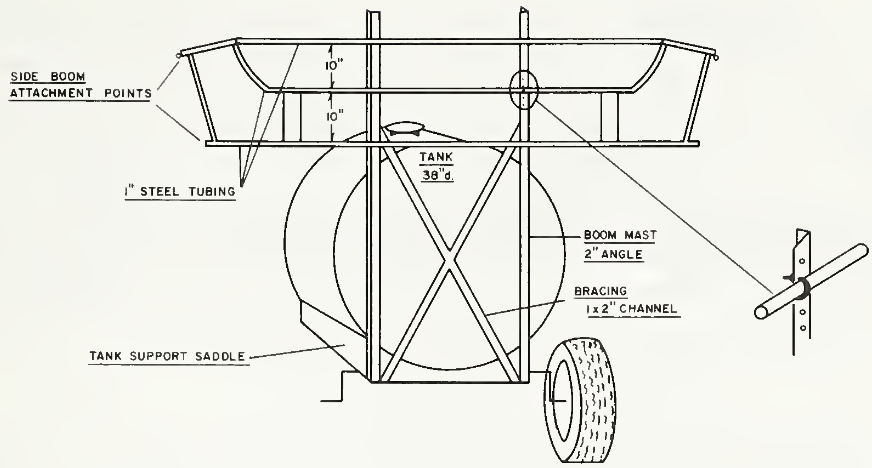

Figure 2.--Support mast for prototype sprayer for sagebrush/rangelands.

The standard booms proved unsatisfactory for operating under the conditions where we wanted to spray. The constant flexing of the metal tubing as the trailer bounced over rough topography caused the tubing to first bend then, ultimately break.

The main booms were redesigned as a tapering lattice with the top and bottom trailer end of the boom constructed of 1-inch square tubing (fig. 3). The interior supports in the lattice were spaced 15 inches from each end and at 12-inch intervals within the framework. The interior supports were constructed of 0.75-inch square tubing alternating with 0.5-square pieces to reduce weight.

As compared with round tubing, the square tubing improves the strength-to-weight ratio and facilitates welding. The hose brackets had to be modified to accept the square tubing. The jib boom was not modified and remained as one-inch diameter round tubing.

The cost of materials for modifying the boom was $75 in 1979. The cost of labor for fabrication in a commercial shop was $75.

Boom Suspension

Equally important with strengthening the interboom for operation on sage-

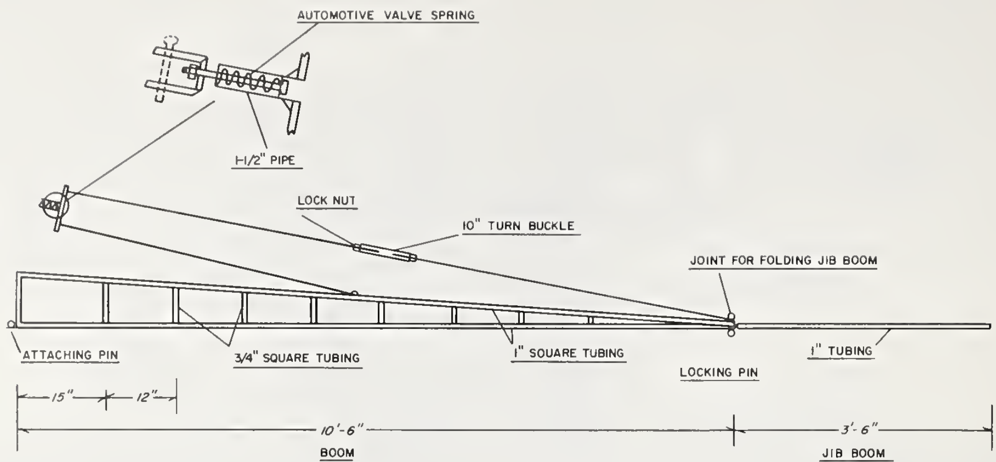

Figure 3.--Lattice boom, suspension rods, and shock absorbers for prototype sprayer for sagebrush rangelands.

brush rangelands is changing the boom suspension to prevent flopping. Normally, the booms are suspended from the mast by chains or cables. When the trailer wheels bounce over rough topography, the flexible suspension allows the booms to flop up in the air, and the resulting return shock breaks the booms and mast.

To prevent flopping of the boom, 3/8-inch diameter rods were substituted for the chains. For adjustment of boom level, a 10-inch turnbuckle was placed in the longer rod (fig. 3). Each turnbuckle was equipped with a locking nut to prevent turning and to maintain tension.

Shock Absorbers

The modified commercial boom used the compression of rubber washers within a 1-1/2-inch diameter pipe as a shock absorber for the boom suspension. Since this system did not prove satisfactory, it was redesigned by replacing the rubber washers with automotive-type valve springs and metal washers and by increasing the diameter of the bolt that compresses the spring and attaches to the primary support from 1/2 to 5/8 of an inch.

Breakaway

The bottom of the boom attaches to the bottom of the primary boom support through a commercial, spring-loaded breakaway hinge. This is a safety feature to prevent damage to the boom by hitting obstruction when either going forward or backing the sprayer.

Transporting the Sprayer Boom

As previously mentioned, the sprayer booms were designed to fold for transport. The lattice design does not permit this folding. The bolt through the shock absorber and the pin at the base of the boom must be removed to detach the booms for transport; however, due to the high clearance of the booms it is possible to pass through many rangeland gates without removing the booms. Sometimes, the wooden gate posts must be slightly shortened.

Removal of the booms was facilitated by placing quick release couplings in the spray hoses. This allowed the boom, hose, and nozzles to be quickly detached as a unit.

Other Required Modification

The sprayer is pulled through standing sagebrush, so clearance and protection of exposed fittings are important. The trailer we used for the sagebrush sprayer had 24 inches of ground clearance. The feed from the spray tank to the pump on the unmodified sprayer was from the bottom of the tank under the trailer frame. This hose had to be protected with a metal shield bolted to the bottom of the frame.

Tank

Spraying sagebrush rangelands does not require a special tank. We have used stainless and plastic tanks successfully. A 300-gal tank has proven adequate.

Agitation

The two basic types of agitation in sprayer tanks are mechanical and hydraulic. The mechanical agitator usually consists of a series of paddles on a shaft running through the tank.

As previously noted, in the hydraulic system of agitation, a pump of considerably higher capacity than that required to supply the boom is used, and the excess flow is forced back into the spray tank through a series of holes in a pipe passing horizontally through the bottom of the tank. The correct procedure for attaching hydraulic agitation nozzles is to connect them as part of the spray system. It is incorrect to attach any nozzles or flow restrictions on the bypass line of the pressure regulator. The operation of a pressure regulator assumes that the bypass is subjected to atmospheric pressure; therefore, it is more efficient to connect the hydraulic agitation line to the spray system immediately after the pump rather than after the pressure regulator. When attached immediately after the pump, agitation occurs any time the pump is operated.

Generally, mechanical agitation requires less power and gives a more uniform dispersion than hydraulic agitation. The initial cost of mechanical agitators is greater. We have found the double bypass hydraulic system to be sat-

isfactory even when spraying wettable powders. The rough topography and obstructions encountered on rangelands result in severe bouncing of the sprayer and contribute to good agitation.

Hoses

On the prototype sagebrush sprayer, we used single-ply hoses with a 3/8-inch inside diameter. This hose can be purchased in bulk from sprayer manufacturers. All connections of hoses were made with quick-release coupling to simplify cleaning and removing.

Commercially manufactured nylon T's with tapered-barbed bodies were used to attach nozzles in the spray lines. The bulk rolls of hose can be cut to facilitate any desired nozzle spacing.

Quick Shutoff Valves

On the sagebrush prototype sprayer are three sections of booms, the right and left 14-ft booms and a 7-ft, 7-inch boom across the rear of the trailer. In the front of the trailer, positioned so they can be easily reached from the tractor seat, are three quick shutoff valves controlling these lines. These valves instantly turn off with single movement of the lever, providing independent control of spray release from each section of the boom.

Screen

An inline strainer with interchangeable screens was mounted between the tank and the pump to protect the pump and to prevent material from reaching the nozzles (fig. 1). When spraying 2,4-D through nozzles with fine openings, use a 100-mesh screen in the strainer. When spraying wettable powders such as atrazine, a 40-mesh screen is required; therefore, a strainer with interchangeable screen is necessary.

Pressure Regulator

A pressure-reducing valve is placed in the line before the quick shutoff valves for the lines to the boom (fig. 1). This regulator ensures that the desired pressure is maintained on the spray lines. A pressure gage with suitable graduations is used to calibrate the regulator. On high-pressure sprayers used for spraying livestock, the pressure gage may not have fine enough graduations for field spraying at low pressures.

Nozzles

Spray nozzles and bodies are manufactured in brass, aluminum, nylon, and stainless steel. Brass nozzles are most common. On the prototype sagebrush sprayer, we used nylon nozzles and bodies, nylon bodies with interchangeable brass nozzles, and nylon nozzles with stainless steel inserts.

Nozzles that produce a flat, fan-shaped spray are considered better than nozzles that produce cone-shaped sprays because they give more uniform coverage and greater drive.

The nozzle flow rate, usually measured in gallons per minute, is determined by the diameter and type of orifice. The nozzle flow rates are given in tables supplied by manufacturers.

The nozzle flow rate and nozzle spacing on the boom are important because these two factors, in conjunction with the speed of the sprayer, establish the amount of spray applied per acre.

For open-field spraying, nozzles are usually spaced from 12 to 24 inches apart. On the sagebrush prototype, 20 nozzles were spaced 22 inches apart on the 35-ft 7-inch boom.

The spacing of the nozzles is partially dependent on the angle of the spray fan. Nozzles are available in a variety of angles, but 65 and 80 degrees are most common. The nozzle spacing for flat fan nozzles depends a great deal on the spray angle. It is best to follow the recommendation that nozzle manufacturers suggest. There is a very definite limit on the maximum spacing recommended for various spray nozzles. It would be best to rely on the manufacturers for their recommended nozzle spacing for their nozzles.

SPRAYER OPERATION

The first step in sprayer operation is calibration. To the unfamiliar, this might appear a difficult operation, but approached on a step-by-step basis and understanding the principles involved leads to easy mastering of the procedure.

Speed

We have determined that for most sagebrush rangelands, 1.5 m/h is the fastest practical speed. This may seem very slow, but at 1.5 m/h 132 ft are traveled per minute. At this speed, driving the tractor through heavy brush, around large rocks, and across drainage ways, while watching the spray coverage, fully occupies the applicator.

Pressure

The nozzle flow rate depends on the pressure maintained. Because on rangeland spraying it is usually desirable to apply relatively low volumes of carrier, pressure should be kept relatively low. On the prototype sagebrush sprayer, we operated at the lowest pressure at which the pump and engine would efficiently function, 30 psi.

Sprayer Application Rate

As previously mentioned, the nozzle flow rate (FR) in gallons per minute can be determined for a particular nozzle and pressure from tables supplied by the manufacturer. For sagebrush spraying, we have found a nylon nozzle with a stainless steel tip insert that delivers an FR of 0.067 g/m at a pressure of 30 psi to be satisfactory. Knowing the speed (1.5 m/h), nozzle spacing (22 inches), and FR (0.067 g/m at 30 psi), we can determine the AR in gallons per acre:

$$AR = \frac{5{,}940 \times FR\ (g/m)}{S\ (m/h) \times \text{nozzle spacing (inches)}}$$

In our case, this would be:

$$AR = \frac{5{,}940 \times 0.067\ g/m}{1.5\ m/h \times 22\text{-inch spacing}}$$

$$= 12\ g/a\ AR$$

The AR can be derived by a more empirical method. Set the desired pressure (30 psi) and fill the spray tank to some absolutely determinable mark, such as the bottom lip of the fill hole. With the throttle set for given resolutions per minute and correct gear ratio for the speed required (1.5 m/h), start the sprayer and drive 40 rods or one-eighth mile. Then measure the amount of water required to refill the tank to exactly the same level. The gallons per acre actually sprayed can be determined by the formula:

$$AR = \frac{\text{Gallons used} \times 66}{\text{Length of boom in feet}}$$

In our case, it would be:

$$AR = \frac{6.36 \times 66}{35} = 12\ g/a$$

Wettable Powders

The spraying of wettable powders, such as the herbicide atrazine, presents special problems. The powdered herbicide does not dissolve, but is merely suspended in the spray solution. The orifice of the nozzle must be large enough to allow the particles of herbicide to pass through. The labels on bags of wettable powder herbicides contain a warning statement concerning the orifice size.

The minimum orifice size for nozzle tips for spraying atrazine is usually given as 13/64 or 0.043 inch. A 50 mesh-screen must be used in the nozzles to allow the suspended herbicide to pass through.

The 13/64-inch orifice at 30 psi produces 0.26 g/m-FR. Our calculations for AR would be:

$$AR = \frac{5{,}940 \times 0.26\ g/m}{1.5\ m/h \times 22\ \text{inches}} = 47\ g/a$$

This is a much higher volume than was used to spray 2,4-D. The higher volume is made necessary by the larger orifice size. The volume could be reduced by increasing speed or reducing pressure; however, it is not practical to run most spray systems below 30 psi, and the type of terrain being sprayed precludes increasing the speed.

Nozzle Screen

When spraying 2,4-D through nozzles with small orifices, use fine 100-mesh screens in the nozzles. When the nozzles are switched to larger orifices for spraying wettable powders, the nozzle screens and inline strainer screens must be changed.

Tips on Sprayer Operation

If the sprayer tank holds 300 gal, do not add the necessary herbicide to 300 gal of water because this would exceed the capacity of the tank. Put the necessary herbicide in first, and then fill with water.

Determining the Amount of Herbicide

Step One

READ THE LABEL! The recommended range of application rates for the specific formulation is given on the label. Be sure the rate used is the appropriate one for the plants that are being sprayed. Normally, the label will list the pesticide application rate (PAR) per acre in pounds of active ingredient (a.i.). For example, 2 lb/acre a.i. of 2,4-D are generally recommended to control sagebrush.

Step Two

Determine concentration of active ingredient. The label will show the amount of active ingredient in each gallon of herbicide formulation. This amount is normally shown as pounds of active ingredient per gallon (for example, Acid Equivalent: 4 lb/gal).

Step Three

Determine the amount of herbicide to add to the tank as follows:

$$\text{Quarts of herbicide per 100 gal of mix} = \frac{\text{Desired herbicide application rate (pounds per acre)} \times 400}{\text{Active ingredient of herbicide (pounds per gallon)} \times \text{AR (g/a)}}$$

In our case:

$$\text{Quarts of herbicide per 100 gal of mix} = \frac{2 \text{ lb/acre} \times 400}{4 \text{ lb/gal} \times 12 \text{ g/a AR}}$$

$$= 16.7 \text{ quarts per 100 gal}$$

For our 300-gal tank, 50 quarts or 12.5 gal of herbicide would be added and the tank then filled with water.

For determining the amount of a wettable powder formulated herbicide to add to the spray tank, a similar procedure is used, following the formula:

$$\text{Pounds of chemical per 100 gal of mix} = \frac{\text{Herbicide application rate (lb/acre)} \times 100}{\text{Percent wp} \times \text{AR (g/a)}}$$

For example, atrazine is usually applied at one pound per acre to control cheatgrass and has 80 percent active ingredient (80 percent wp).

$$\text{Pounds of atrazine per 100 gal of mix} = \frac{1\ \text{lb/acre} \times 100}{0.8\ \text{wp} \times 12\ \text{g/a AR}}$$

$$= 10.4\ \text{lb of atrazine per 100 gal of mix}$$

For the 300-gal tank, this amounts to 31 lb of 80 percent wp atrazine or approximately six 5-lb bags.

Total number of acres that can be sprayed with one load can be determined by dividing the tank capacity by the AR, for example:

$$\frac{\text{300-gal tank capacity}}{\text{12 g/a AR}} = \text{25 acres per load}$$

Cleaning the Sprayer

The most important factor controlling ease of spraying is the cleanliness of the equipment. The sagebrush prototype sprayer has a plastic tank, rubber hoses, and nylon plumbing and nozzle bodies. The only part not resistant to corrosion is the pump housing itself. This is protected by thorough flushing with clean water after spraying and filling the pump with antifreeze.

After spraying, the lines, plumbing, and tank must be thoroughly flushed with clean water. The nozzles and nozzle screens are removed and washed in a mild detergent, thoroughly dried, and stored in plastic bags. The time spent cleaning is well worthwhile in avoiding clogged nozzles.

The openings in the nozzles are machined to a close tolerance. If a nozzle is clogged, care must be taken not to enlarge the openings while cleaning. For fine nozzle tips, a wire from a 100-mesh nozzle screen can be used to remove obstructions.

Nurse Tank

It does no good to clean the sprayer if it is filled with dirty water. A good nurse tank to supply the sprayer makes the job much easier. No herbicide contaminates the nurse tank so it can be used for hauling stock water and other uses on the farm. Most manufacturers of spray tanks also sell nurse tanks. Make sure the tank is clean and free of rust or scale before filling. Fill the tank with clean water. It is a good idea to place an inline strainer between the nurse tank and the pump used to fill the spray tank.

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TECHNICAL NAMES OF COMMON TERMS USED IN THIS PAPER

Common term	Technical name
Plants:	
Big sagebrush	*Artemisia tridentata* Nutt.
Cheatgrass (downy brome)	*Bromus tectorum* L.
Wheatgrass	*Agropyron desertorum* (Fisch. ex Link) Schult.
Herbicide:	
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
2,4-D	(2,4-dichlorophenoxy) acetic acid

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